Reconstruction of the craniomaxillo-mandibular skeleton: problems and solutions

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CHAPTER 10

Summary

In Chapter 1, an introductory overview of the thesis is presented and future trends are discussed. In Chapter 2 the use of bone augmentation materials in Finland from 1994 to 2012 was assessed. In addition, the removal rates of implants placed in combination with autologous bone, xenogeneic grafts and synthetic alloplastic materials were also assessed. The National Institute for Health and Welfare in Finland granted permission to access the raw data of the Finnish Dental Implant Register for implant augmentation materials and removal rates of implants placed in augmented sites from April 1994 to April 2012. A total of 198,538 implants were placed in Finland between 1994 and 2012 in 110,543 operations. A total of 3318 (1.7%) of the placed implants were removed during the observation period. Augmentations were performed in 20,812 (18.8%) operations during 1994–2012. The removal rates of implants placed at sites augmented with autologous bone were 2.31%, xenogeneic materials 0.91% and synthetic alloplastic materials 2.80%. The removal rate was 1.87% when no augmentation material was used. From these results, it can be concluded that the placement of dental implants in conjunction with bone augmentation materials is predictable with a low complication rate.

In chapter 3, oral soft tissue augmentation and grafting procedures are discussed. Such augmentation procedures are often necessary to achieve proper wound closure after tissue deficits resulting from tumour excision, clefts, trauma, dental implants and tooth recessions. Autologous soft tissue grafts still remain the gold standard to acquire a functionally adequate zone of keratinized attached gingiva. However, soft tissue substitutes are being more commonly used because they minimize morbidity and shorten surgical time.

Tissue engineering of oral mucosa represents an interesting alternative for obtaining sufficient autologous tissue for reconstructing oral wounds using biodegradable scaffolds, and may improve vascularization and epithelialization, which are critical for successful outcomes.

Chapter 4 gives an insight into the use of additive manufacturing in maxillofacial reconstruction. Additive manufacturing is the process of joining materials to create objects from digital 3-dimensional (3D) model data, which is a promising technology in oral and maxillofacial surgery. The management of lost craniofacial tissues owing to congenital abnormalities, trauma or cancer treatment poses a challenge to oral and maxillofacial surgeons. Many strategies have been proposed for the management of such defects, but autogenous bone grafts remain the "gold standard" for reconstructive bone surgery. Nevertheless, cell-based treatments using adipose stem cells combined with osteoconductive biomaterials or scaffolds have become a promising alternative to autogenous bone grafts. Such treatment protocols often require customized 3D scaffolds that fulfil functional and esthetical requirements, provide adequate blood supply and meet the load-bearing requirements of the craniomaxillofacial area.

Currently, such customized 3D scaffolds are being manufactured using additive manufacturing technology. In this review, two of the current and emerging modalities for the reconstruction of oral and maxillofacial bone defects are highlighted and discussed; namely, human maxillary sinus floor elevation as a valid model to test bone tissue-engineering approaches enabling the application of 1-step surgical procedures. The seeding of Good Manufacturing Practice–level adipose stem cells on computer-aided manufactured scaffolds to reconstruct large bone defects in a 2-step surgical procedure in which cells are expanded ex vivo and seeded on resorbable scaffolds before implantation is also discussed. Furthermore, imaging-guided tissue engineering technologies that predetermine the surgical location and facilitate the manufacturing of custom-made implants that meet the specific demands of the patient demands are reviewed.

The potential of tissue-engineered constructs designed for the repair of large oral and maxillofacial bone defects in load-bearing situations in a 1-step surgical procedure combining these two innovative approaches is particularly emphasized.

In chapter 5 we discuss the current technological and (pre)clinical advances of 3D bioprinting for use in craniofacial reconstruction and highlight the challenges that need to be addressed in the coming years.

In chapter 6 acute orbital fractures and naso-orbital ethmoid fractures that can result in chronic orbital and naso-orbital deformities are discussed. Understanding the acute injury is the first step in reconstructing the established late deformity. The best management strategy for reconstruction of difficult to manage orbital hypertelorism is to avoid late reconstructions and their sequelae or complications that are extremely difficult to correct.

In Chapter 7 long-term results and complications of patients treated with porous polyethylene (Medpor®) implants in the Department of Oral and Maxillofacial Surgery of VU Medical Centre, Amsterdam over 17 years were assessed. A total of 69 high-density porous polyethylene implants (Medpor® Biomaterial; Porex Surgical, Newman, GA) were used in forty patients (22 males, 18 females). All patients were analysed for gender, age, diagnosis, indications for surgery, follow-up period and postoperative complications. A mean age of 34.1 years was observed. The main reason for implant surgery was post-traumatic functional impairment (27.5%).

Most implants were placed at the mandibular angle and the orbital floor. Unsatisfactory appearance scored the highest in postoperative complications (10.1%) followed by infection rate (7.2%). A comparision of the number of implants placed over the years and the incidence of complications shows that the overall complications rate of porous polyethylene is very low. A consensus regarding antibiotic prophylaxis is needed.

Chapter 8 discusses possible causes of bone loss around failing dental implants using finite element analysis. A further aim was to assess the implications of progressive bone loss on the strains induced by dental implants. Between 2003 and 2009, a total of 3,700 implant operations were performed in a private clinic. Ten patients with 16 fixtures developed severe marginal bone defects. Finite element analysis was used to assess the effective strains produced at the implant-to-bone interface under unidirectional axial loading. These simulations were carried out on four specific implant types – Camlog Plus, Astra Osseo Speed, Straumann BL and Straumann S/SP. All implant types exhibited degraded performance under circular and horizontal bone loss conditions. This was evidenced by an increased distribution of pathological strain intensities (>3000 le), in accordance with the mechanostat hypothesis, in the surrounding bone. Among the implants, the Camlog design seemed to have performed poorly, especially at the chamfer in the implant collar (>25000 με).

Implants are designed to perform under nearly ideal conditions from insertion until osseointegration. However, when the surrounding bone undergoes remodelling, implant geometries can have varied performance, which in some cases can exacerbate bone loss. The results of this study indicate the importance of evaluating implant geometries under clinically observed conditions of progressive bone loss.

Chapter 9 describes the potential of microcomputed tomography (micro-CT) technology in the assessment of retrieved, hence failed dental implants. Cases are presented to illustrate the value of micro-CT imaging techniques in determining possible mechanical causes for dental implant failures. Eight retrieved dental implants were randomly selected from a pool and imaged using a micro-CT device. Source voltages (80 kV to 100 kV) and source-to-detector distances (65 mm to 70 mm) were based on signal quality requirements with an additional criterion of achieving the highest resolution with the sample entirely in the field of view in the projection plane. One additional sample was chosen for histology and tomographic imaging so that the information contained therein could be compared. The micro-CT images displayed high contrast between the implant, bone and background with negligible metal artefacts.

The micro-CT technology used in this study delivered excellent images of the retrieved implants. As a result of the quality and resolution (pixel size: 5.52 µm to 6.15 µm) of the images, surface morphology as well as the internal structures of the retrieved implants could be observed in great detail. The majority of the retrieved implants had increased wear, dents, pits, regular shallow scratches and deep scratches in the implant-to-abutment engagement area. Furthermore, plastic deformations, micro-cracks, and brittle implant fractures were observed in two implants.

The mechanical competence of dental implant components plays a major role in the success of implant treatment. When failures do occur, a non-destructive three-dimensional assessment of such failed implants and their components is helpful in understanding the underlying factors. Micro-CT was found to be a useful tool for the morphologic assessment of retrieved dental implants.

In conclusion, much progress has been made in the development of new treatment strategies for the reconstruction of skull defects. Even though there are a plethora of techniques with various combinations of natural and synthetic materials that can be used in the reconstruction of the craniomaxillo-mandibular skeleton, no one clinical therapy exists that has the ability to undermine complications. A more cohesive integration of virtual and biomechanical preoperative planning combined with patient-specific tissue-engineered constructs could inherently improve surgical outcome and subsequently minimize complications in craniomaxillofacial reconstructive surgery.

To summarize, the future will see more combinations of alloplastic, autologous and tissue-engineered materials in conjunction with advanced computing technologies to create the next generation craniomaxillofacial implants.

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